

BELLCOMM, INC.

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SUBJECT: Effect of Coolant Loop Failure
On Performance of Essential
Spacecraft Function - Case 320

DATE: December 30, 1968

FROM: S. S. Fineblum

MEMORANDUM FOR FILE

During consideration of C' mission options, the Apollo Program Director requested information on the consequences of failure of both coolant loops upon the electronic equipment essential for a safe return. In response, a "quick-look" summary of the coolant loop configuration and cold plate equipment assignments, as well as available test and analytical results, was presented to the Program Director by MAT⁽¹⁾. At that time, the writer initiated an investigation into schedules of cycling the essential electronic equipment to permit task performance required for a safe return while avoiding an overheat condition.

Pending receipt of detailed equipment temperature vs. time results from the thermal vacuum tests on 2TV-1, two available data points for each piece of electronic equipment (initial and maximum temperatures) were used as a basis for interpolating the variation in heating rates with temperature. Since the S-Band Power Amplifier (SBPA) approached its upper temperature limit much more rapidly than the other water-glycol cooled components, it was examined in detail. Its interpolated temperature-versus-time curve was used to infer its approximate cooling rate (See Appendix). Such interpolation resulted in a conservative estimate that a 30-minute "ON" and 60 minute "OFF" cycle for the SBPA would permit the equipment to operate below the maximum permissible temperature (114°F). Other (less sensitive) equipment could operate with even longer "ON" times. Detailed temperature vs. time data ⁽²⁾ subsequently received indicated that the interpolation was close.

Concurrent investigation by Mr. R. M. Scott has shown that on-off cycling of the Guidance and Navigation equipment, within the thermal constraints noted above, can indeed provide a safe emergency return capability in the event of loss of both water-glycol loops ⁽³⁾. A proposed cycling procedure was submitted to the Program Director. ⁽⁴⁾



S. S. Fineblum

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Attachment (NASA-CR-104046) EFFECT OF COOLANT LOOP
References FAILURE ON PERFORMANCE OF ESSENTIAL
Appendix SPACECRAFT FUNCTION (Bellcomm, Inc.) 6 p
Figure 1

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FF No. 60	(PAGES)	(CODE)
	(NASA CR OR TMX OR AD NUMBER)	(CATEGORY)
	[REDACTED]	

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Subject: Response to APO Inquiry -
Effect on Essential Navigation
of Coolant Loop Failure
Case 320

From: S. S. Fineblum

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REFERENCES

1. NASA Letter to Lt. General S. C. Phillips from MAT Director, L. E. Day, "Loss of Both ECS Water-Glycol Coolant Loops During C' Mission," dated October 28, 1968.
2. LDX (Datafax) Message #101, December 6, 1968, from J. Z. Menard to D. D. Arabian/MSC.
3. "WORKING NOTE - Proposed Operating Procedure Upon Loss of Both Water-Glycol Coolant Loops During C' Mission," R. M. Scott, December 17, 1968.
4. "Working Note to Lt. General S. C. Phillips, December 18, 1968, A. P. Boysen, Jr.

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APPENDIX - Method Used to Estimate Equipment Cooling
Rate from Measured Heating Rate in a System
with Heat Leaks.

During the 2TV-1 tests the electronic units with cold plates were operated without coolant flow to simulate coolant system failure. The temperature in the very sensitive S-Band Power Amplifier, for instance, rose from 65°F to 111°F in 57 minutes. As the temperature increased more heat was lost by various thermal leaks from the equipment into the cabin and the adjacent structure. This caused the net heat flux (heat in minus heat out) to decrease and the temperature rise with time to similarly decrease.

The thermal balance for this situation is

$$Q_E + Q_{HL} = I \left[\left(\frac{dT}{d\tau} \right)_E + \left(\frac{dT}{d\tau} \right)_{HL} \right] \quad 1.$$

where Q_E and Q_{HL} are the heat fluxes of electrical energy and heat loss respectively, I is the thermal inertia of the electronic unit plus the cold plate, and $(dT/d\tau)_E$ and $(dT/d\tau)_{HL}$ are the rates of temperature change due only to the electrical energy input (assuming insulated equipment), and the heat leaks, respectively. Further

$$\left(\frac{dT}{d\tau} \right)_E + \left(\frac{dT}{d\tau} \right)_{HL} = \left(\frac{dT}{d\tau} \right)_{E+HL}$$

where $(dT/d\tau)_E$ is the constant slope due to electrical power into the equipment and $(dT/d\tau)_{E+HL}$ the total temperature-time slope.

Initially, when the equipment temperature approximately equals the environmental temperature ($\approx 65^\circ\text{F}$) the heat leak must be essentially zero. That is, in equation 2 the constant electrically powered temperature change initially equals the total temperature change

$$\left(\frac{dT}{d\tau} \right)_E = \left(\frac{dT}{d\tau} \right)_{\text{INITIAL}}$$

By substitution of initial conditions Equation 2 becomes

$$\left(\frac{dT}{d\tau} \right)_{HL} = \left(\frac{dT}{d\tau} \right)_{E+HL} - \left(\frac{dT}{d\tau} \right)_{\text{INITIAL}}$$

Thus the temperature change due to heat leak is the decrease in temperature rise after the initial condition.

This difference was graphically determined as a preliminary rough cut (see Figure 1). The slope at point 1 is subtracted from the initial slope and the difference is the slope at the same temperature, point 2. The method is relatively stable because errors of interpolation at one part of the curve are compensated by errors in the opposite direction in other parts of the interpolated temperature-versus-time-curve.

